Published in: The 12th Triennial IFAC/IFIP/IFORS/IEEE/IMS Symposium "Information Control Problems in Manufacturing" (INCOM'06) – May 17, 18, 19, 2006

# PROCESS IMPROVEMENT IN A VIRTUAL ORGANIZATION FOCUSED ON PRODUCT DEVELOPMENT USING COLLABORATIVE ENVIRONMENTS

**Nicolás Peñaranda[1], Nathalíe Galeano[1], David Romero[1], Ricardo Mejía[2], Arturo Molina[1]**

[1] *CIDYT – ITESM, Campus Monterrey. Monterrey-México*
*Phone: +52-81-83581400 ext. 5355;*
[2] *LIPSI – ESTIA. Bidart-France*
*Phone: +33(0)559.43.84.73*

Abstract: Collaborative Engineering Environments (CEE) have become really important in Virtual Organizations (VO) because they enable the coordination and collaboration among engineering groups, supported by tools and methodologies that enable intellectual capital sharing and engineering activities in real time, among organizations regardless of their locations. A platform that integrates and facilitates the operation in Virtual Organizations focused in manufactured product development, is an important tool that supports a rapid respond to customers, and improve the communication among its members. This paper present a way to improve business process in a VO based on the development and use of a CEE. The methodology presented in this paper was implemented in a real manufacturing VO, improving the product transfer process: the coordinators of each business opportunity easily manage VO information, and VO partners were totally involved during the process. 

Keywords: Collaborative Engineering Environments, Virtual Organizations, System Engineering, Product Transfer.

## 1. INTRODUCTION

Nowadays, traditional serial process of product design and manufacture is replaced by a concurrent design approach that drives in an integrated product development process. Market conditions have led to an upgraded concept where collaborative design must be achieved to support virtual product realization in the new information era.

Specially, when SME (small and medium enterprises) are involved the introduction of a new product, the use of the Virtual Organization (VO) model represents a strategic advantage for these enterprises, making the product development process more efficient and competent, because each organization participates in the engineering process sharing only its core competencies. Subsequently, it is important to understand the VO model.

"VOs are temporary alliances of organizations that come together to share skills or core competencies and resources in order to better respond to business opportunities and produce value-added services and products, and whose cooperation is supported by computer networks". (Camarinha-matos and Afsarmanesh, 2004). One important issue during the life cycle of the VO is the collaboration environment that supports its processes, especially if the VO offers engineering services in a global environment. Engineering services include all the services and activities related with the Integrated Product, Process and Facility Development Process (IPPFD). IPPFD integrates all the activities, methods, information and technologies to conceive the complete Product Life Cycle, where the term product includes process and facilities (Adapted from Tipnis, 1999).

For VOs that offer engineering services, a Collaborative Engineering Environments (CEE) becomes really important, especially during its creation and operation. CEE supports coordination, collaboration and information management processes in a VO aimed to share competencies for engineering process regarding the partners' geographical distribution.

CEE has been defined by several authors using diverse definitions and names, Collaborative Design Environment (Shen, 2003), Web-based manufacturing system (Yang, and Xue, 2003), Virtual CEE (Aca et al. 2003), Virtual Workspace System (Heckel, 1997), and Collaborative Development Environment (Wang and Zhang 2002). However, the common definition is an environment that enables collaboration and interaction among partners on the development of a project regardless of their locations and incorporating information and tools according to an engineering activity. One important reason to use this kind of environments is that product and services are being developed by project work teams distributed into different areas of a company or associated to several companies onto a common project and not necessarily in the same location. This definition is then consequent with the VO model.

Integration of applications and tools that enable exchange of information and knowledge among engineers, in an effective and efficient manner, is an important issue in the development of CEE. These integrated environments must enforce four engineering dimensions: processes, information, organization and technology. Mejia (2004) proposes a methodology for design and integrate CEE in companies; the contribution of this methodology is extended in the VO scope on this paper.

The present work have two main objectives: to present a methodology for process improvement in VO focused on product development process using CEE and to describe the results of implement this methodology in a real manufacturing VO.

Action Research Methodology (Dick, 2002) has been used in this research. Four stages were carried out: 1) Plan Phase is developed the methodology for VO process improvement and, it also is included the definition of the project implementation plan (technical and human resources, project timeline); 2) Act Phase is selected a case study for the implementation of CEE using the methodology proposed; 3) Observe phase is recollected the results of the implementation and 4) Reflection Phase include the documentation of the feedback and experiences in order to improve the first version of the methodology. The methodology for VO Process Improvement presented in this paper already includes the modifications that were done in the reflection phase.

## 2. METHODOLOGY FOR VO PROCESS IMPROVEMENT USING CEE

This methodology supports the process improvement in VOs focused on product development process using CEE, based on the reference model and methodology for reconfigurable IPPFD. The methodology consists in four activities (see Figure 1).

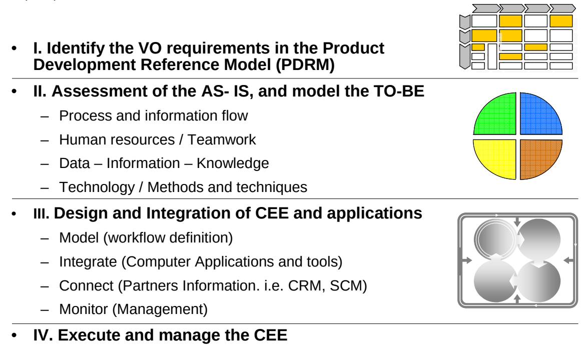


Fig. 1. Methodology for VO process improvement using CEE

### *2.1 Stage I: Identify the VO requirements in the Product Development Reference Model (PDRM).*

The Product Development Reference Model (Aca, 2004) is supported by a map that represents the stages of product lifecycle management (Figure 2). According to this map, the VO should identify the type of business opportunity that will be deal including the activities and its requirements. The stages defined in this map are: 1) Product Design refers to the definition of a new product from the idea to the prototype 2) Process Design refers to the definition of a manufacturing process from the specification identification to the ramp up production; and, 3) Manufacturing System Design includes product/technology transfer and facility design.

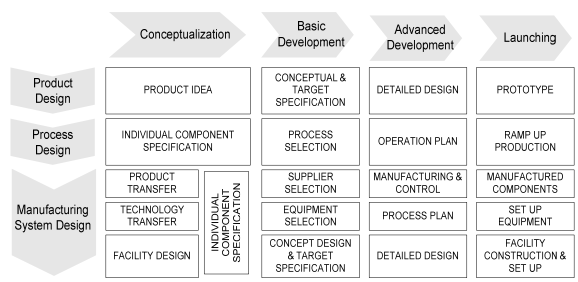


Fig. 2. Map for engineering stages of product lifecycle (Aca, 2004)

### *2.2 Stage II: Assessment of the AS- IS model, and model the TO-BE of the VO Operation.*

The AS-IS model should be developed based on the activities identified in previous stage. The AS-IS VO model represents how the design process (product, process or system manufacturing) is currently executed. In order to perform efficient the AS-IS analysis, the use of graphical representations is suggested, this helps to identify duplicated information, parallel activities, and flow of information and material. Four domains must be graphically represented in the AS-IS model for the identification of the CEE: process, information/knowledge, organization and resources. If necessary, after model the AS-IS process, the TO-BE process should be modelled, including modifications for improving the process efficiency. The TO-BE model captures the team's processredesign for the VO Collaboration Engineering Environment. This TO-BE model will be the base to define the CEE workflow in the following stage.

*2.3 Stage III. Design and integration of CEE and its applications.*

After the AS-IS model is identified and understood (or TO-BE model, if it is the case) four main steps must be followed for integrate the CEE:

*Modelling the workflow.* Workflow modelling allows to analyze the whole VO design process and to visualize how it works. The model also helps identifying possible problems of information flow, like duplicated and unnecessary activities, as well as showing which are the core activities and core resources in the VO operation. There are some standard tools and languages recommended to model business process, such as: IDEF0 (Integrated definition methods), UML (Unified Modelling Language) and BPMN (Business Process Management Notation).

*Selection and Integration of engineering applications:* Several computer based information systems have been introduced to support IPPFD methodology, which integrates all the activities, methods, information and technologies to conceive the complete Product Life Cycle. Taxonomy for these systems includes (see Table 1). (Mejía et al., 2004). For each type of VO the CEE supporting tools used in each category may change, but in general these categories include the tools necessary to enable VO integrated product development supported by CEE.

Table 1. Classification of CEE tools (Adapted form Mejía et al., 2004)

| Functional | Knowledge / Information Management | Collaboration | Coordination |
|---|---|---|---|
| *To carry out and support specific functions* | *To share and manage Information and knowledge* | *To Interact and Communicate* | *To manage and control tasks* |
| • CAD/CAE/ FEA<br>• Intelligent CAD<br>• QFD/AMEF/ IDEF0<br>• DFM/DFA<br>• Rapid prototyping<br>• CAPP/CAM<br>• MAS | • Knowledge based engineering systems (KBES)<br>• Product Model<br>• Product Data Management<br>• Manufacturing Model<br>• Knowledge repository<br>• Data mining technique. | • STEP/IGES<br>• Net Meeting<br>• Forums<br>• Multicasting<br>• E-mail<br>• Groupware<br>• CSCW<br>• e-payment | • Project Management<br>• Workflow |
| | • Product Lifecycle Management (PLM)<br>• Asset Lifecycle Management (ALM)<br>• e-management/e-production<br>• e-project<br>• Business Process Management (BPM) | | |

*Connect environment and applications using standard and web protocols.* Two groups of connections can be identified in this process. First group includes marketing information exchange (e.g. Web pages, e-catalogues) and interconnection of Manufacturing / Production information (e.g. e-RFQ, ERP, on-line Capacities). The second group includes the information exchange among partner’s functional tools (e.g. CAD/CAM/CAE files). Various Web-based manufacturing systems have been developed in the past decade for supporting activities in different product development life-cycle phases, (marketing, design, process planning, production, distribution, service).

Figure 3 describes the VO manufacturing system infrastructure. The VO management tools are a group of Web-based manufacturing systems located in a Web-platform that can be accessed by any VO member anywhere in the world using Web-tools and Web-browsers. The Web-tools provided to the VO members are the integration of VO member tools in a connect environment known as CEE. The use of a CEE in a VO, focused on product development, increases efficiencies, decreases product development led-time and improves quality through cooperative partners work (VO members).

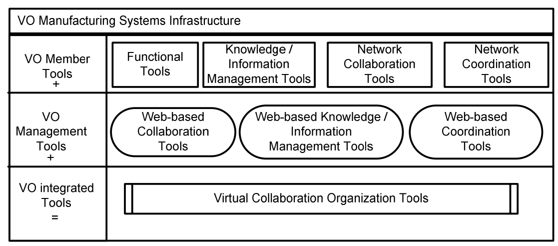


Fig. 3. VO Manufacturing Systems Infrastructure.

*Definition of performance measures and monitoring techniques.* Measurable parameters and monitoring techniques that allow VO managers to coordinate, track and control the product development process are identified. The workflow model has to be considered, in order to have a guideline for associating all the measurable data. This data includes, for example, the VO resources involved in each activity (human and technological), which are important for cost estimations (important measurable parameter) and also for workload analysis. Furthermore, assigned dates and time for each partner are also included, in order to control delays or precedence problems based on unfinished activities. Similarly, activities’ input and outputs should be controlled, for manage information flow and availability of further activities.

*2.4 Stage IV. Model execution and evaluation.*

After the environment is technologically integrated and implemented, it has to be managed and the loop for continuous process management is closed by the use of Monitoring techniques. It provides external visibility into what is occurring when the product development in the VO is being executed. The process management tracks events and data from the Workflow environment execution and provides both real-time and historical tracking of what is occurring in the workflow engine. Finally an improvement process is performed, in order to analyze a possible new TO-BE model (the current process in execution is converted now in the AS-IS) and maybe new design improvements can be proposed to improve the business process. This final phase close the loop in the methodology.

## 3. CASE STUDY

This case study is developed in IECOS[1], which is a small company, spin-off at ITESM (Instituto Tecnológico de Monterrey, Campus Monterrey) and has been developed based on the VO model.

The Value Proposition of IECOS is to optimize the performance in "make-to-order and engineering-to-order" business processes based-on an architecture that inherently integrates customers and suppliers. IECOS administers an associated enterprise network, including metalworking, CNC, plastic and finishing processes. Thanks to this network, IECOS has the capacity to offer a complete variety of products and processes; consequently, the collaboration between all its members is really important. In order to improve IECOS supplier and customer integration, the methodology for VO process improvement using CEEs was implemented. Following, product transfer process, for IECOS' aerospace customers, is analyzed using the methodology described in section 2, results and conclusions of this analysis and implementation are also presented.

### *3.1 Stage I. Identify IECOS requirements in the Product Development Reference Model.*

Using the map for engineering steps in product life cycle (Figure 2), IECOS product transfer model is composed of individual component specification, supplier selection, manufacturing & control, manufactured components. IECOS product transfer process, components are manufactured by conventional processes and the suppliers fulfil requirements in cost, time and quality. Usually IECOS receive product drawings and customer specification and then, product transfer process starts with the analysis of the product requirements and the selection of suppliers. This model presents four stages:

- *Conceptualization*, product information is identified. The Bill of Materials (BOM) is analized in order to identify materials, standard components, quality standards and delivery times according to customer requirements.
- *Basic Development*, Manufacturing capacities and capabilities from different companies are evaluated in order to integrate their competences for develop the project. Suppliers for standard parts are also selected.
- *Advanced Development*, components are manufactured by the selected suppliers. Control variables are defined and controlled along the manufacturing process.
- *Launching*, components are delivered to IECOS; final quality controls are done and documented. Final product is packed and delivered to the customer.

### *3.2 Stage II. Assessment of the AS- IS model, and model the TO-BE of the VO Operation.*

IECOS build the product transfer information system thinking forward to improve the decentralized information workflow between their clients and suppliers (see Figure 4). In the AS-IS model all the information flows through e-mail, fax or sometimes by phone.

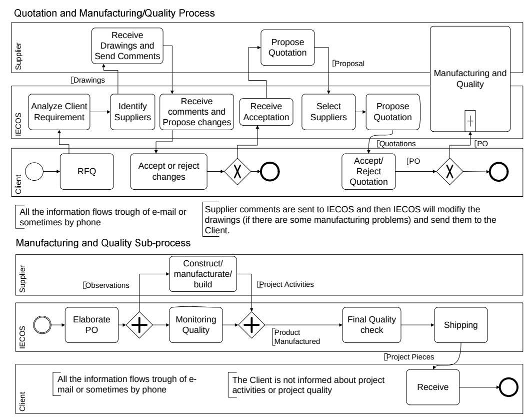


Fig. 4. AS-IS model for IECOS quotation and manufacturing process (using BPMN)

IECOS TO-BE model proposes a web-based application that provides to the clients order management capabilities, order status visibility and transaction history. Also, it offers to the suppliers a "quick start" for on-line order fulfilment. With this application IECOS will offers a cost-effective method for support client requirements electronically. (See Figure 5). The mayor difference between the AS-IS and TO-BE Model is the information flow, which is represented in Fig. 6.

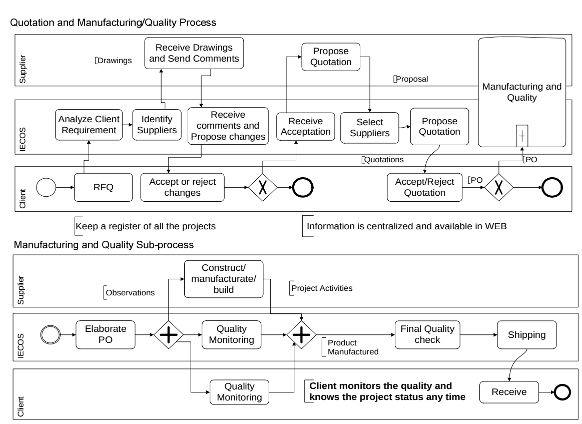


Fig. 5. TO-BE Model for IECOS quotation and manufacturing process (BPMN).

[1] Acronym of "Integration Engineering and Construction Systems SA de CV" (www.iecos.com)

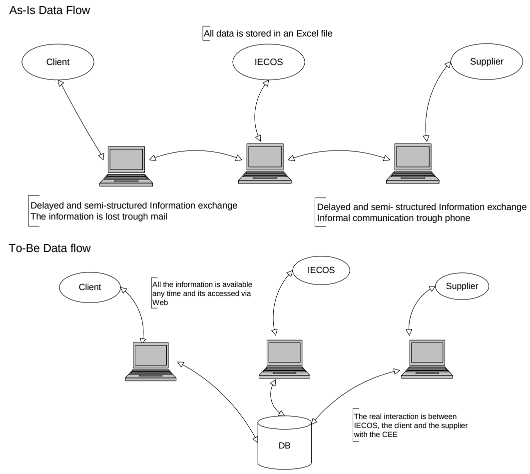


Fig. 6 AS-IS and TO-BE Information flow in IECOS

### *3.3 Stage III. Design and integration of CEE and its application.*

*Modelling the workflow*. The system consists in two main flows (Figure 5); the first one is a quotation flow. It starts when the client sent a RFQ (request for quotation) to IECOS. After that, IECOS can distribute this project between the specific suppliers adding in the drawings some technical comments. Suppliers can download the files needed to make their quotation and also can send questions or comments to IECOS. This comments and questions can be approved by IECOS to be seen by the client or can be used only for the communication between the suppliers and IECOS. Once the suppliers have the quotation for the project, they upload it in the CEE and IECOS can see all the quotations made by the different suppliers and can choose the best one (Figure 7). IECOS will consolidate in the CEE the final quotation for the client, including all components prices, total lead time, and special requirements. Then the client can evaluate the quotation and decide if they will send a Purchase Order (PO). When the PO is sent to IECOS, the manufacturing of the pieces starts. IECOS adds the PO information in the CEE indicating to each supplier the parts that should manufacture.

During manufacturing suppliers and IECOS add information about project process, usually for the 25%, 50%, 75% and 100% of the project, so the client knows exactly the real project progress and the activities that were needed to complete the project. Any problem that occurs during manufacturing can be solved using this CEE, making comments or questions. When the project is finished, IECOS includes a photo of the product in the system and client can observe the final product. The client also knows if the product is already sent and when it will be arrive. This CEE also manages the administrative issues of the project so administrative personal can know if the PO is already paid or if it doesn’t.

*Selection and integration of engineering applications:* The VO members in this project have different tools. Suppliers use functional tools (CAD systems), collaboration tools (STEP/IGES and e-mail) and coordination tools (Project Management). IECOS present IBM infrastructure to manage the information using data base management (DB2), functional tools (CATIA-DELMIA), collaboration tools (Quick Place, Same Time) and coordination tools (MQSeries Workflow’s and SmarTeam).

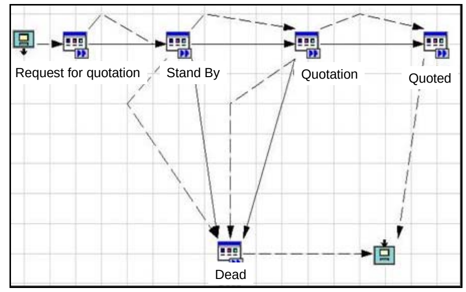


Fig. 7. Quotation process in MQSeries Workflow’s

*Connect environment and applications using standard and web protocols.* The architecture was made with Java server Pages (JSP’s), which is a group of pages accessed by Internet using the J2EE java’s technology. The JSP’s interact with servlets and java files, and those accessed a data base DB2 and MQSeries Workflow. All this architecture make possible the interaction between the clients, IECOS and the suppliers, and the possibility to define, document, test, control, execute, improve and integrate the business’ process of the organization.

*Definition of performance measures and monitoring techniques.* The performance in this process is monitored by the relation between the number of Quoted Projects, Manufactured Projects, Stand by Projects and “Dead Projects” (projects not executed). Also the system generates economic statistics, relations between projects paid and projects pending to pay. These statistics can be filtered by a range of days, months or years, but also by status (manufacturing, sent, received, and dead) and can be generated for a specific project.

The final design of the CEE includes the following features: Real-time receipt of electronic purchase orders and change orders; Full visibility to order status and transaction history; Robust customer communications handling including purchase order acknowledgements, change order acknowledgements, advanced shipping notifications; Receive and send attachments; On-line ad-hoc queries (ask and response); Secure messaging, translation, and monitoring services guaranteeing 100% transaction accuracy, among others.

### *3.4 Stage IV. Model execution and evaluation.*

The results of CEE impacted IECOS information management process. Some advantages identified are: Reduces order fulfilments costs (5%); On-line order client communications, shipping notifications and other customer communications; The purchase order is immediately processed; Visibility of order status and order history; Complete customer support through improved order processing; On Time in the lead Time; Additional supply-chain collaboration tools; Offer strategic value-added to the customer aimed to improve customer loyalty

## 4. CONCLUSIONS AND LESSONS LEARNED

A methodology for design and implement CEE in VO is presented in this paper. This methodology includes different tools for achieve inter/intra-enterprise integration. The results of implementing a CEE in a real VO, using this methodology, was also presented. The CEE implemented in the study case improves the VO product transfer process; the coordinators of each business opportunity easily managed VO information and partners in the VO were totally involved during the product transfer process.

IECOS CEE will serve in a nearly future as the base platform for use future supply chain collaboration tools between a supplier and its customers. Suppliers can reduce costs to serve their customer through lower order processing costs and improved customer data. The CEE solution is a market differentiated and value-added customer solution that can be used to create customer loyalty. IECOS CEE can also be used for industrial suppliers seeking to increase service levels and connectivity with their clients through the creation of a VO, providing an automated supply management options via the Internet.

During the case analyzed some important factors for the implementation of these tools in a VO were identified such as the cultural change and the learning curve. It is very difficult to change the way that some suppliers are used to work. Convince them that using this CEE can improve the collaboration and the information management process is an important task for the success of the tool. On the other hand, it is important to consider the time to learn and train on these tools. Persons that are going to develop this environment should be involved in the training process, because some times the tools are very specialized and suppliers may need continuous training and support.

This systematic methodology could be extended to any VO focused on product transfer. However, as part of further research activities, it is important to validate this methodology in other areas, like product design (Mechatronic design), transfer technology and facilities design.

## ACKNOWLEDGEMENTS

The research presented in this document is a contribution for the ECOLEAD Project, funded by the European Community, FP6 IP 506958. The authors acknowledge the support of the IBM SUR Grant, the CEMEX's KM-BPM Grant, and the Chair in Mechatronics from ITESM - Campus Monterrey.

## REFERENCES

Aca J., 2004, *Reference Model and Methodology to Configure/Reconfigure Integrated Product, Process and Facility Development Processes*, Master Thesis in Manufacturing systems, ITESM.

Aca, J., Mejía, R., Velandia, M., García, E., Galeano, N., Ahuett, H., Molina, A., and Wright, P., 2003, *Integrated Product Development in Virtual Enterprises Supported by Web-based Applications*. In L.M. Camarinha-Matos, H. Afsarmanesh (Eds.), Process and Foundations for Virtual Organizations (Kluwer Academic Publishers), pp. 361-268.

Camarinha-Matos, L.M.; Afsarmanesh, H., 2004. *"Collaborative Networked Organizations – A research agenda for emerging business models"*. Springer, USA, pp 8-9.

Chun-Che Huang, 2004, *"A multi-agent Approach to collaborative design of modular products"*. Concurrent Engineering: Research and Applications, Volume 2, Number 1.

Clements B., 2003/04, *"Lifecycle Management"*, IEE Manufacturing Engineer.

Dick, B.(2002). "Action research: action and research" In the seminar: "Doing good action research" held at Southern Cross University, February 18, 2002

Heckel, J. 1997, *The Virtual Workspace System: An enabling technology for collaborative engineering applications.* Proceedings of the Workshop on Enabling Technologies for Collaborative Enterprise, Boston, MA, pp. 10-16.

Mejía R, Canché L, Rodríguez C, Ahuett H, Molina A and Augenbroe G, 2004, *Designing a HUB to offer e-Engineering brokerage services for Virtual Enterprises*. In L.M. Camarinha-Matos (Ed), Virtual enterprises and collaborative networks (Kluwer Academic Publishers), pp. 453-460.

Mejía R. 2004. *Methodology For Design and Integration of Collaborative E- Engineering Environments*, Master Thesis in Manufacturing systems, ITESM.

Shen, W., 2003, *Editorial of the special issue on knowledge sharing in collaborative design environments.* Computers in Industry, 52, 1-3.

Tipnis V.A., 1999, *"Evolving Issues in Product Life Cycle Design: Design for Sustainability"*, Chapter 13, in Handbook of Life Cycle Engineering: Concepts, models and technologies, Edited by A. Molina, A. Kusiak and J. Sanchez, London, Kluwer Academic Publishers, 1999, pp. 399 - 412.

Wang HF. and Zhang YL., 2002, CAD/CAM *integrated system in collaborative development environment*. Robotics and Computer Integrated Manufacturing, 18, 135–145.

Yang H., Zue D., 2003, *"Recent research on developing Web-Based Manufacturing systemes: a review"*. International Journal of Production Research.